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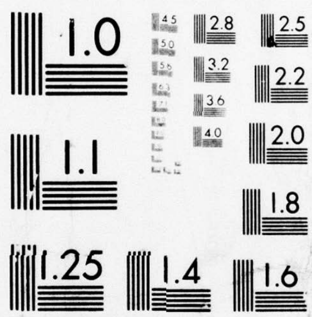

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ENGINEERING AND SCIENTIFIC RESEARCH AT WES



Miscellaneous Paper 0-72-3 December 1972



## EARTHQUAKE EFFECTS ON ARCH DAMS,

*by J. P. Balsara, Weapons Effects Laboratory*

The response of concrete arch dams subjected to earthquake forces is extremely complex. The complexities arise due to the nature of the random excitation, the complex structural geometries, and the interaction of the structure with the reservoir and foundation. In order to develop better design procedures, the total behavior of the structure under its loading environment must be considered.

Both physical models and three-dimensional finite element methods are being used by U. S. Army Engineer Waterways Experiment Station (WES) engineers to study the response of the North Fork Dam to vibratory and simulated seismic-type motions. The prototype dam is located on the North Fork of the American River, about 5 miles east of Auburn, California. It is a constant-angle arch structure with a maximum height of 155 ft and a crest length of 620 ft. The central 200 ft of the crest acts as an overflow spillway (fig. 1).



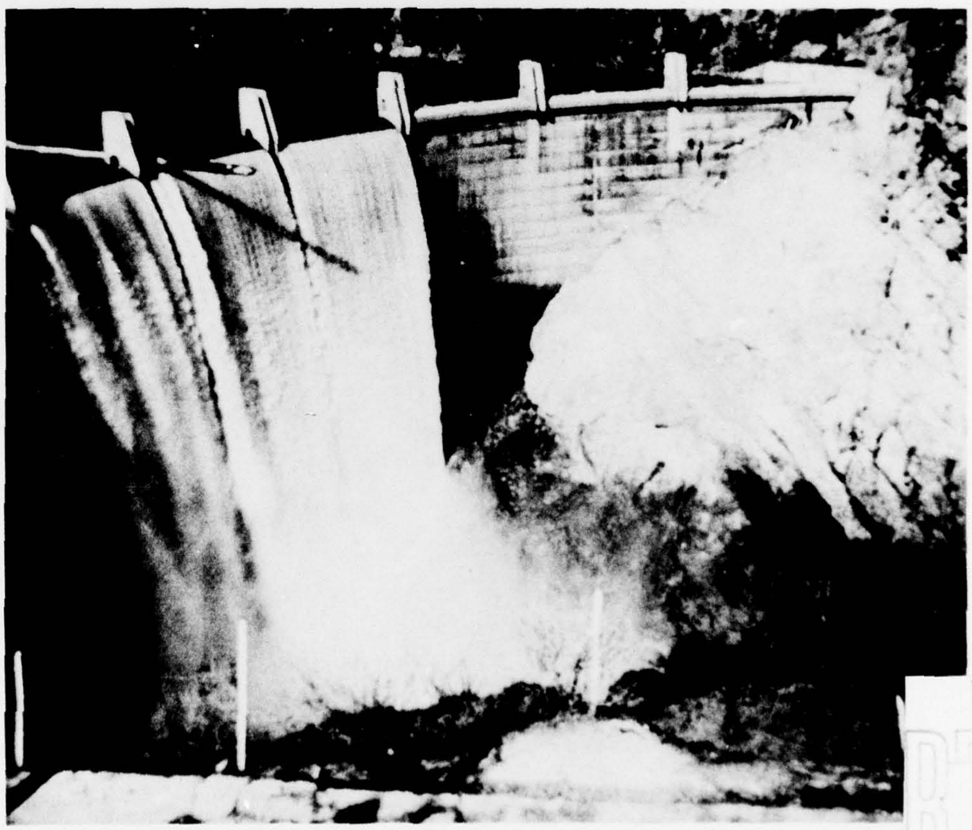

*Fig. 1. View of prototype North Fork Dam*

A 1:24-scale model of the dam and a section of the reservoir was constructed at the WES Big Black River test site to study the dynamic behavior of such structures. During the first phase of testing, natural frequencies for the various modes and damping characteristics were determined by inducing vibrations along the crest and the base of the model dam. Fig. 2 shows the fully instrumented model dam with the vibrators mounted on the crest. The results of finite element calculations using the grid shown in fig. 3 and subsequent analyses on a slice of the dam indicated that the effects of the dam foundation, surrounding soil, and the water mass must be considered in predicting the response of model and prototype dams of this type.

Additional vibration tests and tests simulating earthquake motions are to be conducted on the model dam. Tests with vibrators located on the crest of the prototype dam are also planned. The results of these tests will be used to evaluate the physical model and the finite element method with regard to earthquake response predictions.

*Fig. 2. 1:24-scale model of North Fork Dam*

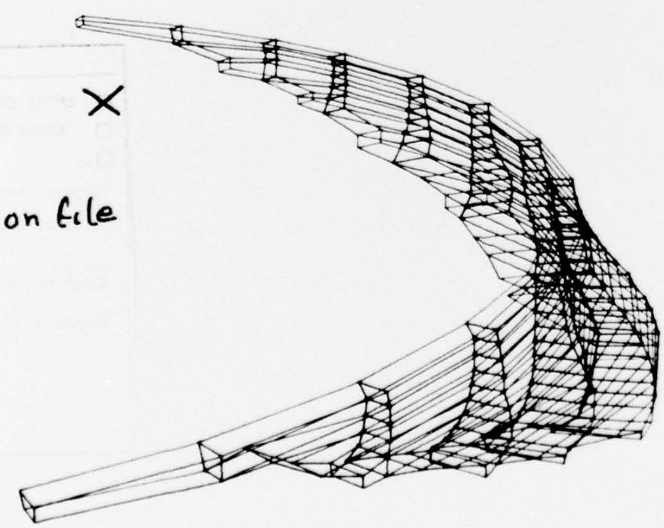

*Fig. 3. Finite element grid of model dam*

**SCALE-MODEL VEHICLES,** *by C. E. Green, Mobility and Environmental Systems Laboratory*

Terrain features occur in many sizes, shapes, and spacings, producing innumerable possible combinations of surface configuration. Their effects on vehicle performance range from a simple reduction in speed necessitated by vehicle vibration or maneuvering to complete immobilization caused by obstacle-vehicle interference. Before vehicle performance can be evaluated with a reasonable degree of accuracy, a means of characterizing the effects of surface configuration must be developed. Previous investigations with prototype vehicles and constructed obstacles have involved much work and high cost.

At the U. S. Army Engineer Waterways Experiment Station (WES) there is a new "mini-look" with regard to methods for predicting performance of vehicles as related to surface geometry or to the geometric irregularities of the terrain surface, such as logs, boulders, steep banks, ditches, etc. In a study under way at WES these investigations are being conducted with self-propelled scale-model vehicles.

At present, the scale-model vehicle fleet (fig. 1) consists of one tracked vehicle (the M60 tank) and three wheeled vehicles (the M561, 1-1/4-ton, 6x6, cargo carrier; the M35A2, 2-1/2-ton, 6x6, cargo truck; and the articulated M520E1, 8-ton, 4x4, cargo carrier). The tracked vehicle is to a scale of 1:20 and the wheeled vehicles are to a scale of 1:15. The M60 tank and the M35A2 truck have been standard equipment in the Army system for many years, whereas the M520E1 and the M561 are relatively new to the system and are considered *high-mobility* vehicles. The vehicle characteristics of the models are scaled from their prototype counterparts. The models are radio-controlled (fig. 2) and can turn in either direction, back up or go forward, speed up or slow down, and change gears.

There are many single variables or combinations of variables that might cause a vehicle to become immobilized, such as lack of traction, and size, shape, and spacing of obstacles. Some examples of immobilizations that might

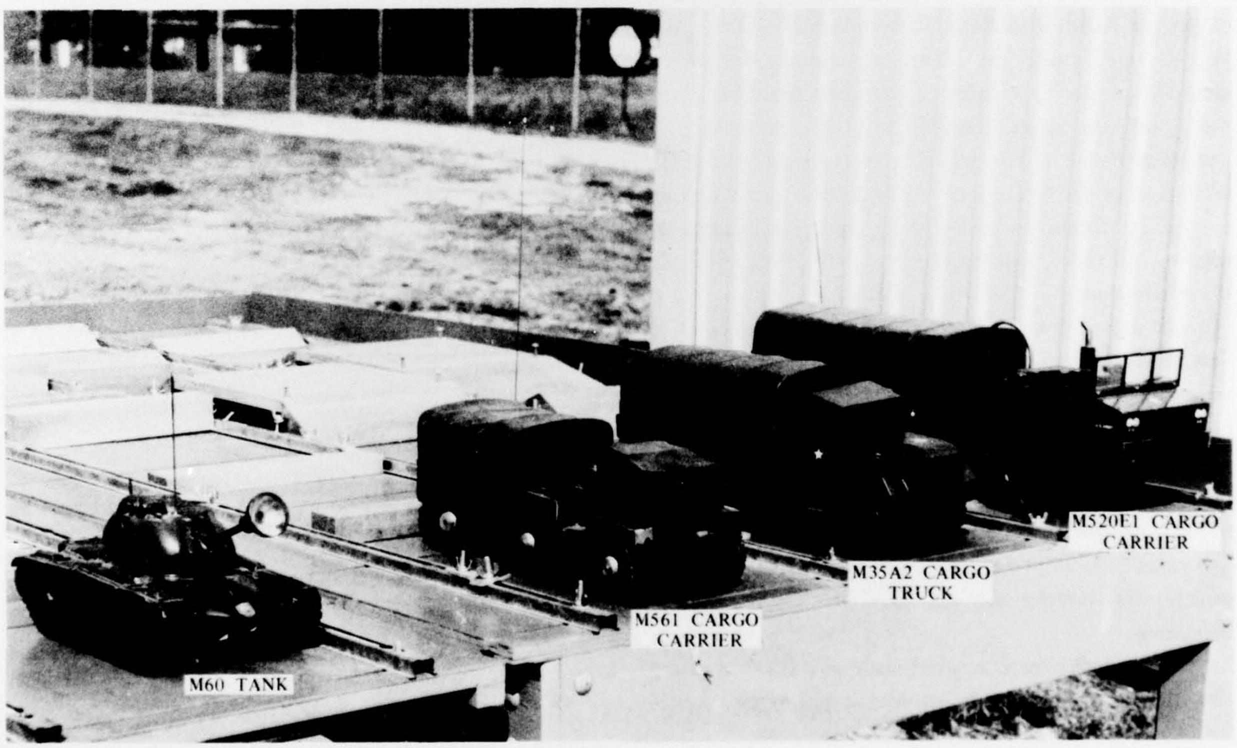


*Fig. 1. Scale-model vehicle fleet*

*Fig. 2. Typical scale-model immobilizations*

occur are shown in fig. 2. The M60 tank and M520E1 cargo carrier are shown immobilized due to lack of traction; the M35A2 cargo truck and M561 cargo carrier are shown immobilized due to interference between the vehicle and the surface while attempting to negotiate a triangular-shaped ditch and dike, respectively. The main advantage of the scale-model study is that it provides an economical means for establishing the combinations of vehicles, obstacles, and traction that will produce vehicle immobilizations.

To date, the scale-model vehicles have been used to determine with a high degree of accuracy (a) the maximum size and shape of concave (ditch) and convex (dike) obstacles the vehicles can negotiate without interference on various tractive surfaces, (b) effects of spacing of several types of obstacles on obstacle negotiability, (c) effects of surface traction on obstacle negotiability, and (d) the maximum long slope (at least two times the length of the vehicle) the vehicles can negotiate for various traction conditions.

These determinations were made at a fraction of the cost that would have been involved if prototype vehicles had been used. Future tests are expected to yield more information on other problems (such as maneuverability, power requirements, and vehicle design) that are encountered in vehicle mobility.

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## REPORTS RECENTLY PUBLISHED BY WES

*Concrete Laboratory:*

Laboratory Investigation of 4-1/2-in. Aggregate Concrete Mixtures with High Water-Cement Ratios, by W. O. Tynes, Technical Report C-72-3, Sep 1972.

*Hydraulics Laboratory:*

Wave Damping Effects of Fibrous Screens, by G. H. Keulegan, Research Report H-72-2, Sep 1972.

Navigation Conditions and Filling and Emptying System, New Bankhead Lock, Black Warrior River, Alabama, by N. R. Oswalt, J. H. Ables, Jr., and T. E. Murphy, Technical Report H-72-6, Sep 1972.

*Mobility and Environmental Systems Laboratory:*

Ground Truth Requirements for Remote Sensor Data Acquisition and Analysis, by L. E. Link, Jr., Miscellaneous Paper M-72-8, Nov 1972.

*Soils and Pavements Laboratory:*

Movement of Variable-Density Inclusions in Wet Sand under Blast Loading, by E. B. Perry, Miscellaneous Paper S-72-37, Sep 1972.

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*Weapons Effects Laboratory:*

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Shock Wave Propagation in Shallow Water, by L. Miller and J. N. Strange, Technical Report N-72-9, Sep 1972.

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